Relationship between land surface albedo and precipitation in the Sahel region

SUMMARY

Key Points

- Land surface albedo is a key forcing parameter for the climate system controlling the radiative energy budget;
- The objective of this use case is to assess the relation between an albedo change and a different precipitation regime in the Sahel region;
- The Geostationary Surface Albedo (GSA) algorithm jointly developed at the Space Applications Institute of the Joint Research Centre (JRC) of the European Commission and EUMETSAT has been chosen for the Use Case. GSA has been also selected for the generation of a GEO-ring albedo within the WMO SCOPE-CM initiative (Lattanzio et al. 2012).

Service

- Adaptation
- Agriculture
- Energy
- Mitigation

End User(s)

- Government agencies
- Researchers

Intermediate User(s)

- WMO Regional Climate Centers (RCCs)
- Climate modeling community
- Research institutes and academia

Application(s)

Land surface albedo is a key forcing parameter for the climate system controlling the radiative energy budget. Its monitoring is of primary importance for an understanding of the climate system. The value of the land surface albedo changes in space and time, depending on both natural processes (vegetation growth, rain and snowfall and snow melting, wildfires, etc.) and human activities (forestation and deforestation, harvesting crops, anthropogenic fires, etc.). Ground-based measurements are of great importance for the assessment and evaluation of local and regional variability and change, while satellite remote sensing offers a unique opportunity for documenting and monitoring the spatial surface albedo distribution, its variability, and change at continental scales. Observations acquired by geostationary satellites have the advantages of offering both a long-term dataset and an angular sampling of the surface as well as providing diurnal sampling of key parameters influencing the retrieval, such as cloud cover and aerosol load. The objective of this Use Case is to see if a change of surface albedo due to a change in the rainfall regime can be quantified using satellite observations. This study focuses on the region of Sahel in the African continent.

Essential Climate Variables

—Atmosphere

- Precipitation

—Land

- Albedo
- Fraction of absorbed photosynthetically active radiation (FAPAR)

Climate Data Records

See table

Agencies

- EUMETSAT

Climate Data Records Used

Data Record	RecordID	DOI
MSA Release 1 0-degree	10954	10.15770/EUM_SEC_CLM_0001
Rainfall from the Global Precipitation Climatology Project (GPCP)	11627	10.7289/V5RX998Z
Fraction of Absorbed Photosynthetically Active Radiation (FAPAR) derived from Wide Field-of-view Sensor (SeaWiFS) observations	N/A	10.1029/2005JD006511

Satellite Observations

See Table 1.

Sustainability

The use case is an application of land surface albedo to check if satellite observations are suitable to assess an albedo change due to a change in the precipitation regime in the Sahel region.

Table 1: Instrument details for the geostationary satellites used in the method consolidation phase. The SSP position, the image acquisition repeat cycle (RC), the VIS band spectral width, the SSP instrument square pixel size (PS) and the digitzation levels (DLs) are given.

Satellite	Location (SSP)	RC (h)	VIS band (μm)	PS (km)	DL (bits)
Meteosat–2	0°	0.5	0.40–1.08	2.5	6
Meteosat–7	0°	0.5	0.40–1.08	2.5	8

DESCRIPTION

The Sahel region is a transition belt between the Sahara desert in the north and the tropical savannas to the south, spanning from the Atlantic Ocean to the Red Sea. The population living in this region suffered from heavy droughts in the 1970s and the 1980s. It is known that low rainfall and human activities, such as overgrazing and deforestation, and fires cause depletion of vegetation, which leads to a brighter surface (higher surface albedo) observable from space. As early as 1977, Charney et al. suggested a mechanism relating the increase in surface albedo to a decrease in precipitation. This rather local effect is coupled with a complex large-scale feedback mechanism (Figure 1), triggered by variations at interhemispheric scale of sea surface temperature that regulate the strength of the African Monsoon, which is essential for Sahel rainfall (Giannini 2003; Zeng 2003). The baseline dataset for this study is the Meteosat Surface Albedo (MSA) Climate Data Record (CDR) (EUMETSAT 2009), that describes the evolution of the surface albedo with a temporal sampling of about 10 days. This data record was developed and included also in support of the SCOPE-CM WMO framework (Lattanzio et al. 2012). These data, together with rainfall data from the Global Precipitation Climatology Project (GPCP), were used to assess the impact of changes in rainfall on land surface albedo, as described by Govaerts and Lattanzio 2007. In addition, proxy data for vegetation growth were determined from the Fraction of Absorbed Photosynthetically Active Radiation (FAPAR), derived from Wide Field-of-view Sensor (SeaWiFS) observations (Ceccherini, Gobron, and Robustelli 2013).

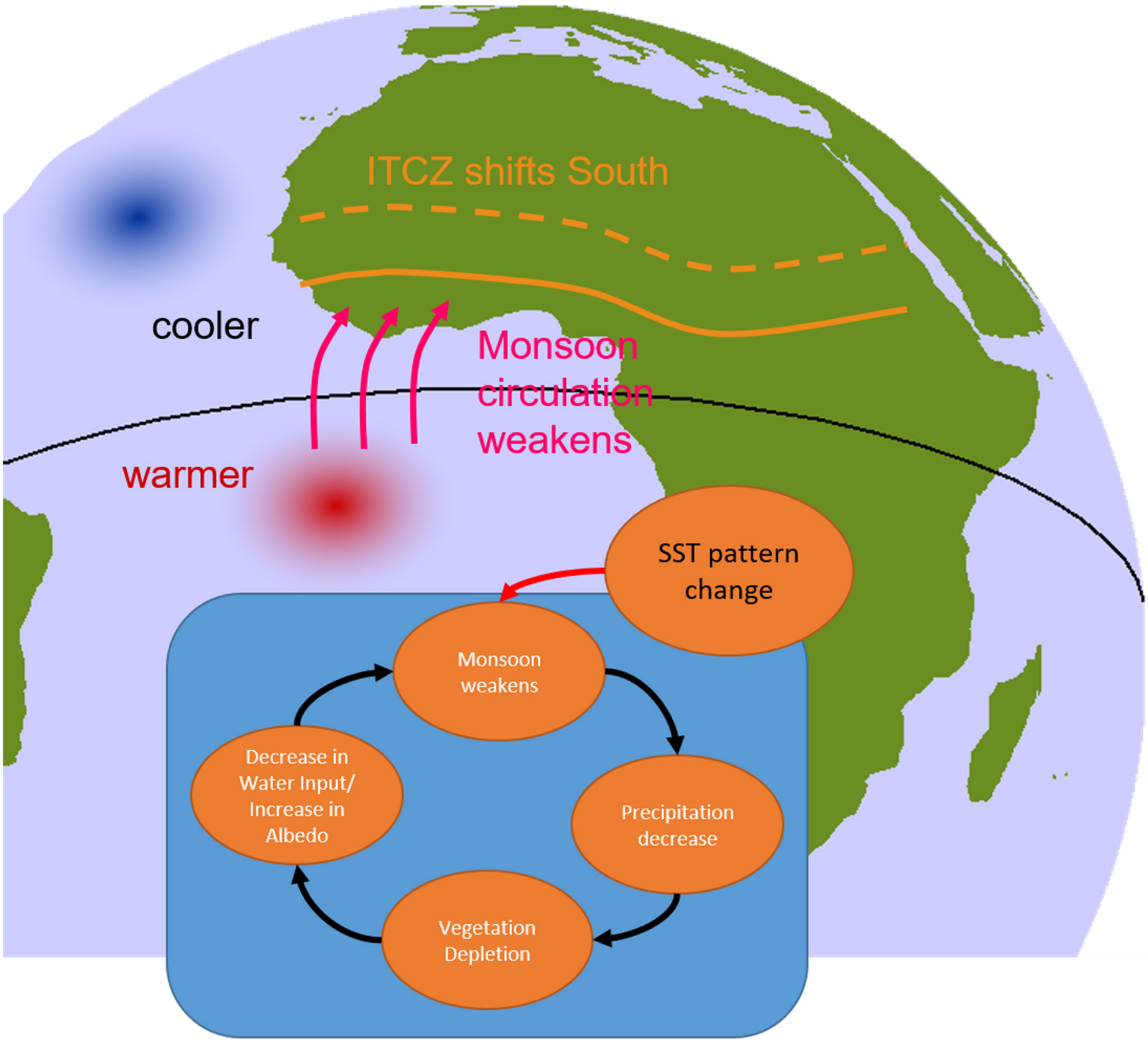

Figure 1: Model proposed to explain the connection between Sea Surface Temperature (SST), precipitation, vegetation and land surface albedo (Giannini 2003; Zeng 2003).

Figure 2 shows the existence of a seasonal relationship between the three quantities, in particular, there is a one-month lag between rainfall and vegetation growth. The surface albedo follows the changes in surface vegetation coverage.

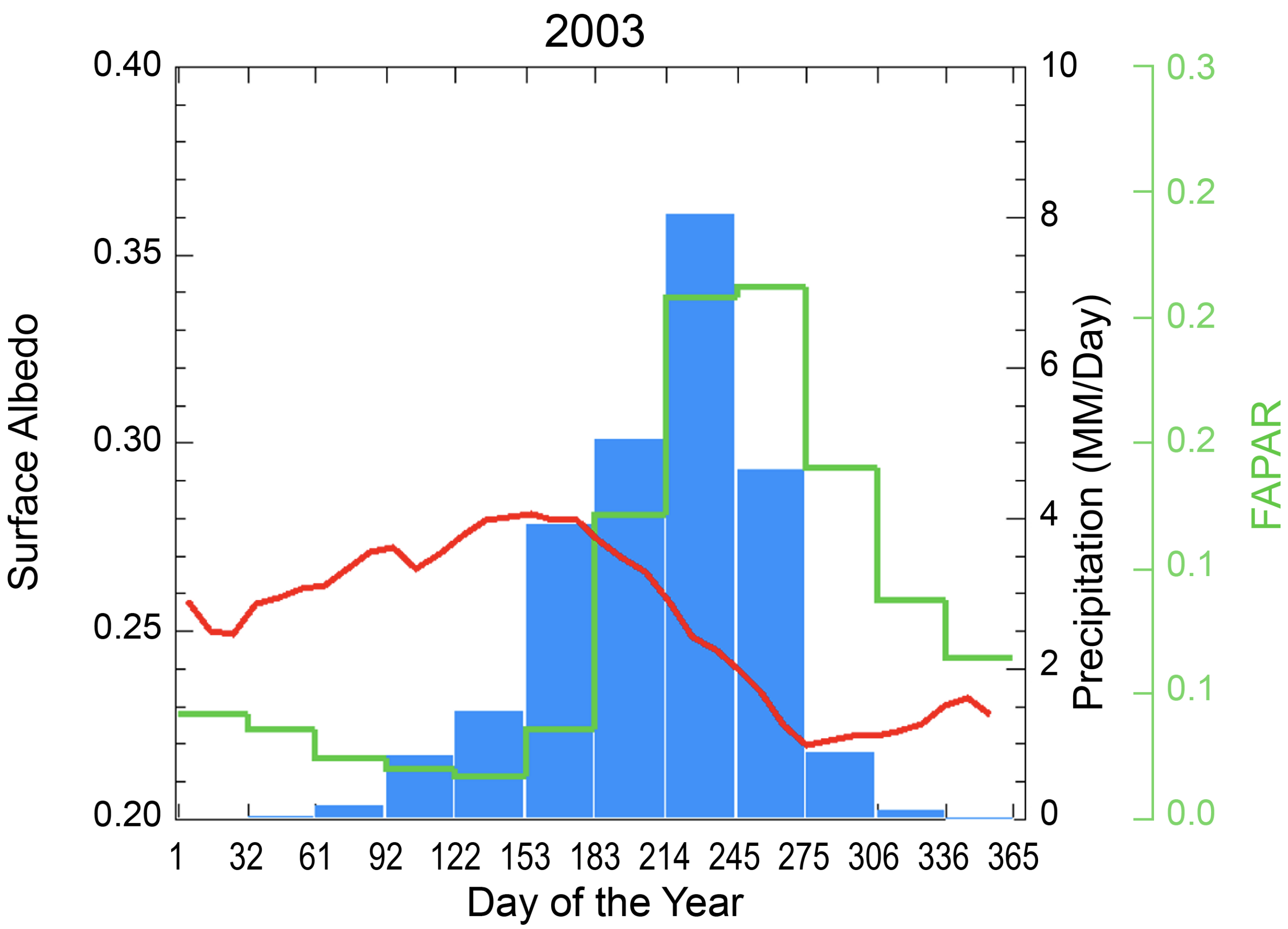

Figure 2: Seasonal monthly variation for the Sahel of precipitations (blue), FAPAR (green), and broadband land surface albedo (red). The figure is taken from Govaerts and Lattanzio 2008.

To demonstrate the magnitude of albedo response to large positive or negative anomalies in rainfall, two contrasting years were analyzed. Time-series of the rainfall index during the period June to October over the Sahel region (Janowiak 1988), as shown in Figure 3, reveal two years, 1984 and 2003, since the start of satellite observations, that exhibit a large difference in precipitation amounts — with 1984 being a very dry year and 2003 being a rather wet year.

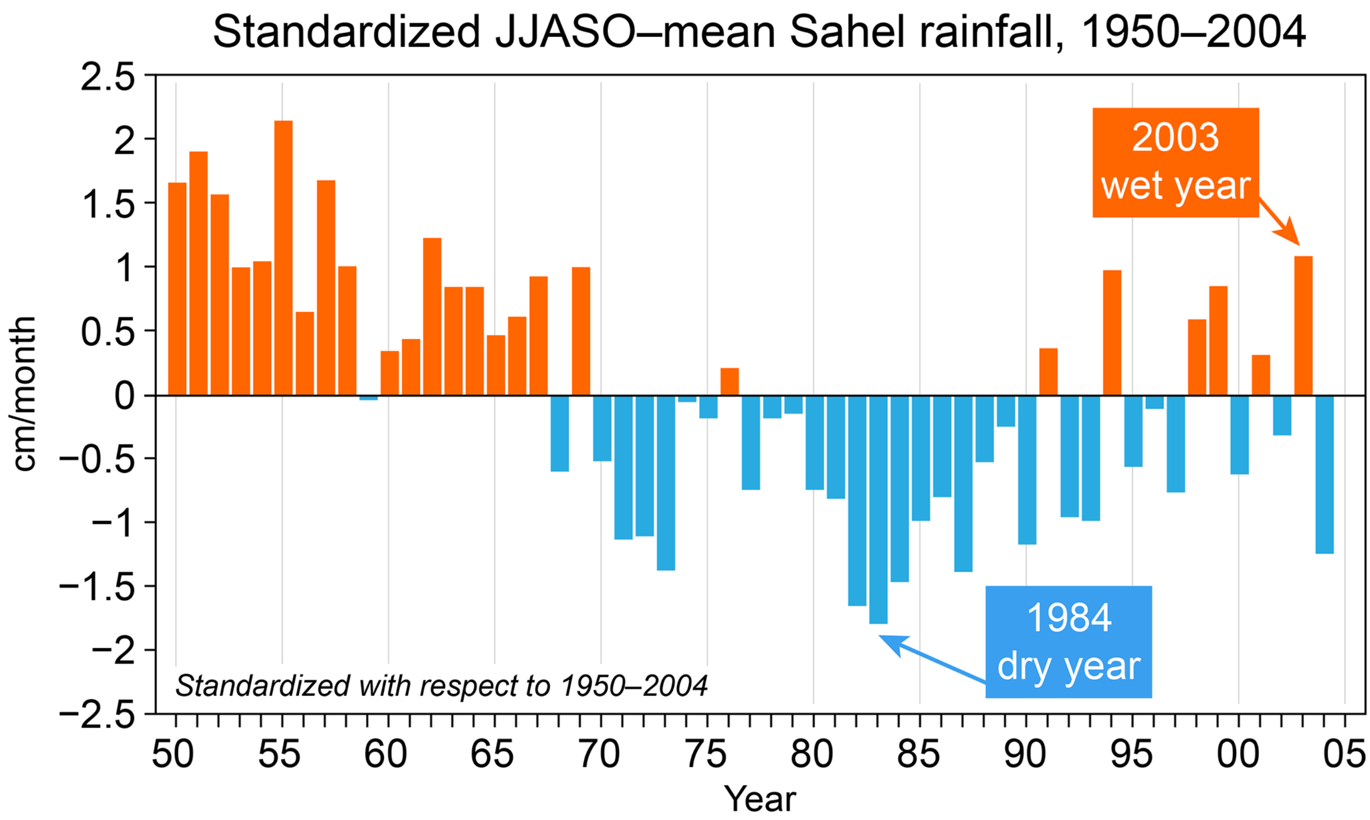

Figure 3: Sahel rainfall index, June-October between 1950 and 2004 in cm/month. 1984, with a much less than normal rainfall, and 2003, with more than normal rainfall, were used to assess if this was causing differences in surface albedo. The averages are standardized in a way that the mean and the standard deviation of the series are 0 and 1 (figure from the Joint Institute for the Study of the Atmosphere and Ocean of the University of Washington).

The Meteosat derived land surface albedo during the period August, September, October of the dry year (1984) and the wet year (2003) were compared. Figure 4 shows the difference map of mean surface albedo. Differences due to the retrieval uncertainty have been removed in order to clearly highlight the real albedo ASO change between 1984 and 2003 (Govaerts and Lattanzio 2007).

The map in Figure 4 highlights a generally lower surface albedo in 2003 compared to 1984. The absolute magnitude of the difference is not geographically uniform and varies over the Sahel belt. Govaerts and Lattanzio (2008) concluded that regions particularly affected by the 1980s drought are essentially located into a narrow band of about 2° latitude along 16°N running from 18°W up to 20°E.

Within this geographical area, the mean broadband surface albedo decreases from 0.35±0.04 in 1984 to 0.27±0.03 in 2003, which corresponds to an absolute difference of 0.08±0.05, because of the lack of rainfall of 200 mm/year over the season in 1984.

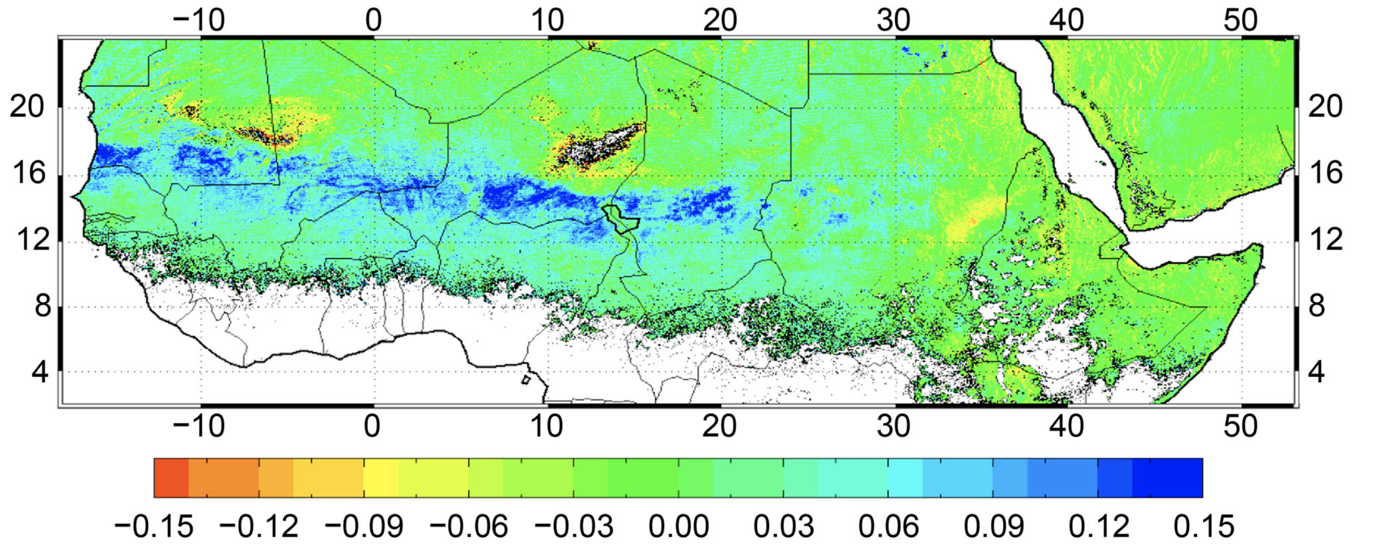

Figure 4: Broadband surface albedo differences (1984–2003) for the period August, September, October. Figure taken from Govaerts and Lattanzio 2008.

Recently, EUMETSAT published a new Geostationary Surface Albedo (GSA) climate record (EUMETSAT 2020a; 2020b; 2020c), which further improved the quality of the surface albedo retrievals, as compared to the first climate record used in this study.

The major improvement originates from the usage of a cloud mask significantly reducing errors due to undetected clouds in the first version of the climate record. In addition, the new data record spans a much longer period that enables further studies of the African climate.

Key peer-reviewed publications on the project:

Ceccherini, Guido, Nadine Gobron, and Monica Robustelli. 2013. 'Harmonization of Fraction of Absorbed Photosynthetically Active Radiation (FAPAR) from Sea-ViewingWide Field-of-View Sensor (SeaWiFS) and Medium Resolution Imaging Spectrometer Instrument (MERIS).' *Remote Sensing* 5 (7): 3357–76. https://doi.org/10.3390/rs5073357.

Charney, Jule, William J. Quirk, Shu-hsien Chow, and Jack Kornfield. 1977. 'A Comparative Study of the Effects of Albedo Change on Drought in Semi–Arid Regions.' *Journal of the Atmospheric Sciences* 34 (9): 1366–85. https://doi.org/10.1175/1520-0469(1977)034<1366:ACSOTE>2.0.CO;2.

EUMETSAT. 2009. 'MTPMSA1Meteosat Surface Albedo - MFG - 0 Degree.' BUFR, 720.0 MB. https://doi.org/10.15770/EUM_SEC_CLM_0001.

———. 2020a. 'GSAR20000GSA Level 2 Climate Data Record Release 2 - MFG and MSG - 0 Degree.' NetCDF4. EUMETSAT. https://doi.org/10.15770/EUM_SEC_CLM_0023.

———. 2020b. 'GSAR20570GSA Level 2 Climate Data Record Release 2 - MFG - 57 Degree.' NetCDF4. EUMETSAT. https://doi.org/10.15770/EUM_SEC_CLM_0024.

———. 2020c. 'GSAR20630GSA Level 2 Climate Data Record Release 2 - MFG - 63 Degree.' NetCDF4. EUMETSAT. https://doi.org/10.15770/EUM_SEC_CLM_0025.

Giannini, A. 2003. ‘Oceanic Forcing of Sahel Rainfall on Interannual to Interdecadal Time Scales.’ *Science* 302 (5647): 1027–30. https://doi.org/10.1126/science.1089357.

Govaerts, Y., and A. Lattanzio. 2008. ‘Estimation of Surface Albedo Increase during the Eighties Sahel Drought from Meteosat Observations.’ *Global and Planetary Change* 64 (3–4): 139–45. https://doi.org/10.1016/j.gloplacha.2008.04.004.

Govaerts, Y. M., and A. Lattanzio. 2007. ‘Retrieval Error Estimation of Surface Albedo Derived from Geostationary Large Band Satellite Observations: Application to Meteosat-2 and Meteosat-7 Data.’ *Journal of Geophysical Research*: Atmospheres 112 (D5). https://doi.org/10.1029/2006JD007313.

Janowiak, John E. 1988. ‘An Investigation of Interannual Rainfall Variability in Africa.’ *Journal of Climate* 1 (3): 240–55. https://doi.org/10.1175/1520-0442(1988)001<0240:AIOIRV>2.0.CO;2.

Lattanzio, A., J. Schulz, J. Matthews, A. Okuyama, B. Theodore, J. J. Bates, K. R. Knapp, Y. Kosaka, and L. Schüller. 2012. ‘Land Surface Albedo from Geostationary Satellites: A Multiagency Collaboration within SCOPE-CM.’ *Bulletin of the American Meteorological Society* 94 (2): 205–14. https://doi.org/10.1175/BAMS-D-11-00230.1.

Zeng, Ning. 2003. ‘Drought in the Sahel.’ *Science* 302 (5647): 999. https://doi.org/10.1126/science.1090849.

INFORMATION FLOW

Observations

- Meteosat-2
- Meteosat-7

Climate Data Records

- MSA Release 1 0 degree mission: DOI: 10.15770/EUM_SEC_CLM_0001
- GPCP daily precipitation: 10.7289/V5RX998Z
- European Commission - FAPAR (europa.eu) https://doi.org/10.1029/2005JD006511

Application

- This study shows the key role that observations and retrieval of geophysical parameters from geostationary satellites might have in climate studies. In particular in regions such as the Sahel, and in general in a belt of 30 degrees north and south of the equator, where the number of measurements from polar satellite instruments is often too low to address variations of parameters like the land surface albedo.

Decision Making

- This Use Case can indirectly support a climate mitigation and adaptation process as well as contribute to the assessment of environmental impact of human activities. No direct usage for decision-making.

The improvement of any application of climate data records derived by historical data such as Meteosat First Generation is directly linked to any improvements in the input level 1 data. A better calibration or geolocation and rectification will immediately have a huge impact on the quality of the retrieved geophysical quantity such as surface albedo. Then, as any other land quantity, the retrieval of land surface albedo is also directly dependent on the ability to screen out clouds.